CM caps

WHAT IS CLAIMED IS:

1. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies wherein said fuel bundle includes:

PI a plurality of fuel rods for placement within said channel, each said fuel rod containing fissile material for producing nuclear reaction when in the presence of sufficient moderating water coolant and moderated neutrons;

PI a lower tie plate for supporting said bundle of fuel rods within said channel, said lower tie plate joining the bottom of said channel to close the bottom end of said channel, said lower tie plate providing defined apertures for the inflow of water coolant in said channel between said fuel rods for generation of steam during said nuclear reaction;

PI said plurality of fuel rods extending from said lower tie plate wherein a single phase region of said water in said bundle is defined to an upward portion of said bundle wherein a annular flow regime of said water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

PI an upper tie plate for supporting the upper end of said bundle of fuel rods, said upper tie plate joining the top of said channel, said upper tie plate providing apertures for the outflow of water and generated steam in said channel during said nuclear reaction;

PI spacers intermediate said upper and lower tie plates at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly including a first group of spacers in said lower region of said fuel bundle and a second group of spacers in said upper annular flow regime of said fuel bundle;

PI a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said partial length fuel rods terminating at ends within the upper region of said fuel bundle before reaching said upper tie plate and causing deceased pressure drop in said annular

flow regime of said fuel bundle during said nuclear steam generating reaction;

the improvement to said bundle comprising:

means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods whereby improved critical power performance is achieved at said fuel bundle having said part length fuel rods.

2. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods restores part but not all of said decreased pressure drop realized by said part length fuel rods.

3. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods includes decreased spacer pitch in the upper two phase region of said fuel bundle.

4. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods includes vanes attached to said spacers.

5. The invention of claim 3 and wherein said second group of spacers has decreasing pitch progressively upward of the upper two phase region of said bundle.

6. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods includes swirl vanes.

7. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part

length fuel rods includes spacers having increased vertical height.

8. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods is attached to the end of said part length rod.

9. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods is attached to one of said spacers.

10. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods is attached to said upper tie plate.

11. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods includes a cone, said cone disposed with the apex there of is downward disposed to and towards the end of said part length rod.

12. The invention of claim 1 and wherein a plurality of part length rods are placed within said fuel bundle and said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods overlies more than one of said part length rods.

13. The invention of claim 1 and wherein said upper tie plate defines an aperture and said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods passes through said upper tie plate at said aperture.

14. The invention of claim 1 and wherein said means in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods is attached to a water rod.

15. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies wherein said fuel bundle includes:

a plurality of fuel rods for placement within said channel, each said fuel rod containing fissile material for producing nuclear reaction when in the presence of sufficient moderating water coolant and moderated neutrons;

a lower tie plate for supporting said bundle of fuel rods within said channel, said lower tie plate joining the bottom of said channel to close the bottom end of said channel, said lower tie plate providing defined apertures for the inflow of water coolant in said channel between said fuel rods for generation of steam during said nuclear reaction;

said plurality of fuel rods extending from said lower tie plate wherein a single phase region of said water in said bundle is defined to an upward portion of said bundle wherein a annular flow regime of said water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

an upper tie plate for supporting the upper end of said bundle of fuel rods, said upper tie plate joining the top of said channel, said upper tie plate providing apertures for the outflow of water and generated steam in said channel during said nuclear reaction;

spacers intermediate said upper and lower tie plates at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly including a first group of spacers in said lower region of said fuel bundle and a second group of spacers in said upper annular flow regime of said fuel bundle;

a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said partial length fuel rods terminating at ends within

the upper region of said fuel bundle before reaching said upper tie plate and causing deceased pressure drop in said annular flow regime of said fuel bundle during said nuclear steam generating reaction;

the improvement to said bundle comprising:

means associated with at least some of said second group of spacers in the annular flow regime of said fuel bundle for restoring at least some of the decreased pressure drop realized by said part length fuel rods whereby improved critical power performance is achieved at said fuel bundle having said part length fuel rods.

16. The invention of claim 15 and wherein said means associated with at least some of said second group of spacers restores part but not all of said decreased pressure drop realized by said part length fuel rods.

17. The invention of claim 15 and wherein said means associated with at least some of said second group of spacers includes decreased spacer pitch in the annular flow regime of said fuel bundle.

18. The invention of claim 15 and wherein said means associated with at least some of said second group of spacers includes vanes attached to said spacers.

19. The invention of claim 17 and wherein said second group of spacers has decreasing pitch progressively upward of the annular flow regime of said bundle.

20. The invention of claim 15 and wherein said means associated with at least some of said second group of spacers includes swirl vanes.

21. The invention of claim 15 and wherein said means associated with at least some of said second group of spacers includes spacers having increased vertical height.

22. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies wherein said fuel bundle includes:

a plurality of fuel rods for placement within said channel, each said fuel rod containing fissile material for producing nuclear reaction when in the presence of sufficient moderating water coolant and moderated neutrons;

a lower tie plate for supporting said bundle of fuel rods within said channel, said lower tie plate joining the bottom of said channel to close the bottom end of said channel, said lower tie plate providing defined apertures for the inflow of water coolant in said channel between said fuel rods for generation of steam during said nuclear reaction;

said plurality of fuel rods extending from said lower tie plate wherein a single phase region of said water in said bundle is defined to an upward portion of said bundle wherein an annular flow regime of said water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

an upper tie plate for supporting the upper end of said bundle of fuel rods, said upper tie plate joining the top of said channel, said upper tie plate providing apertures for the outflow of water and generated steam in said channel during said nuclear reaction;

spacers intermediate said upper and lower tie plates at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly including a first group of spacers in a lower region of said fuel bundle and a second group of spacers in said annular flow regime of said fuel bundle;

a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said partial length fuel rods terminating within the upper region of said fuel bundle before reaching said upper tie plate and causing deceased pressure drop in said upper annular flow regime of said fuel bundle during said nuclear steam generating reaction;

P1 the improvement to the distribution of said bundle comprising:

P2 said spacers of said first group of spacers having at least one first vertical distribution in a first lower portion of said assembly in a first vertical interval;

P2 said spacers of said second group having at least one second and smaller vertical distribution in said annular flow regime of said fuel bundle to restore at least some of said decreased pressure drop in said upper annular flow regime of said fuel bundle whereby the spacers having at least one second and smaller vertical distribution present improved critical power in the upper annular flow regime of said bundle.

23. The invention of claim 22 and wherein said matrix B is a 10 by 10 matrix.

24. The invention of claim 22 and including up to twelve part length rods.

25. The invention of claim 22 and wherein said spacers include ferrule spacers.

26. The invention of claim 22 and where the upper most spacer in said second group of spacers is an inconel spacer having low pressure drop and minimal pressure drop on the passing annular flow regime in said upper two phase region of said fuel bundle.

27. The invention of claim 22 and including:

P1 at least one large water rod extending in said fuel bundle having moderator contained therein for providing to said upper two-phase region of said fuel bundle additional moderator for moderating reaction produced fast neutrons to reaction continuing thermal neutrons, said large water rod occupying a portion of the fuel rod positions in said fuel rod matrix.

28. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies an improved fuel bundle comprising:

a plurality of fuel rods for placement within said channel, each of said fuel rods containing fissile material for producing nuclear reaction when the presence of sufficient water coolant and moderated neutrons;

a lower tie plate for supporting said bundle of fuel rods within said channel, said lower tie plate joining the bottom of said channel close to said channel, said lower tie plate providing defined apertures for the inflow of water in said channel between said fuel rods for the generation of steam during said nuclear reaction;

said plurality of fuel rods extending from said lower tie plate wherein a single phase region of water in said bundle is defined to an upward portion of said bundle wherein an annular flow regime of water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

an upper tie plate for supporting the upper end of said bundle of fuel rods, said upper tie plate joining the top of said channel, said upper tie plate providing defined the apertures for the outflow of water and steam in said channel from the generation of steam during said nuclear reactions;

a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said part length fuel rods terminating within the upper region of said bundle before reaching said upper tie plate and causing deceased pressure drop in said upper annular flow regime of said fuel bundle during said nuclear steam generation reaction;

spacers intermediate said upper and lower tie plate at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly, said spacers including a first group of spacers in said lower region of said fuel bundle and a second group of spacers in said upper annular flow regime of said fuel bundle;

said spacers of said first group having at least one first vertical distribution from said lower tie plate in said lower region of said fuel bundle;

said spacers of said second group having at least one second and smaller vertical distribution in said upper annular flow regime of said fuel bundle to said upper tie plate whereby the spacers present above said part length fuel rod restores pressure drop and improves the critical power in the upper annular flow regime of said fuel bundle.

29. The invention of claim 28 and wherein said matrix is a 10 x 10 matrix.

30. The invention of claim 28 and wherein all said part length rods are of different lengths.

31. The invention of claim 28 and wherein said part length rods have one full length rod between said part length rods in said channel.

32. The invention of claim 28 and wherein said spacers include ferrule spacers.

33. The invention of claim 28 and where the upper most spacer in said bundle is an inconel spacer having low pressure drop and minimal pressure drop on the passing two phase flow in said upper two phase region of said fuel bundle.

34. The invention of claim 28 and including:

at least one large water rod extending in said fuel bundle having moderator contained therein for providing to said upper two-phase region of said fuel bundle additional moderator for moderating reaction produced fast neutrons to reaction continuing thermal neutrons, said large water rod occupying a portion of the fuel rod positions in said fuel rod matrix.

35. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies, wherein said fuel bundle includes:

a fuel channel having vertically extending walls forming a continuous channel around a fuel assembly volume, said channel being open at the bottom end for engagement to a lower tie plate and open at the upper end for engagement to an upper tie plate;

a plurality of rods for placement within said channel, each said rod containing fissile material for producing nuclear reaction when in the presence of water coolant;

a lower tie plate for supporting said bundle of rods within said channel, said lower tie plate joining the bottom of said channel to close the bottom end of said channel, said lower tie plate providing defined apertures for the inflow of water in said channel between said rods for generation of steam during said nuclear reaction;

said plurality of fuel rods extending from said lower tie plate to an upward portion of said bundle wherein an annular flow regime of said water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

an upper tie plate for supporting the upper end of said bundle of rods, said upper tie plate joining the top of said channel to close the top end of said channel, said upper tie plate providing apertures for the outflow of water and steam in said channel from a generation of steam during said nuclear reaction;

spacers intermediate said upper and lower tie plates at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly, said spacers including a first group of spacers in said lower region of said fuel bundle and a second group of spacers in said upper annular flow regime of said fuel bundle;

a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said partial length rods terminating within the annular

flow regime of said fuel bundle before reaching said upper tie plate and causing deceased pressure drop in said upper annular flow regime of said fuel bundle;

P1 the improvement to said spacer distribution comprising:

P2 a plurality of said second group of spacers in said upper annular flow regime of said fuel bundle having swirl vanes attached to said spacers to restore at least some of said decreased pressure drop in the upper annular flow regime of the fuel bundle whereby the critical power of said fuel bundle is improved.

36. The invention of claim 35 and wherein said second group of spacers with said swirl vanes in the upper annular flow regime of said fuel bundle has the same pitch as said spacers without said swirl vanes.

37. The invention of claim 35 and wherein said second group of spacers with said swirl vanes in the upper annular flow regime of said fuel bundle has an decreased pitch over said spacers without said swirl vanes.

38. The invention of claim 35 and wherein said matrix is a 10 by 10 matrix.

39. The invention of claim 35 and including up to twelve part length rods.

40. The invention of claim 38 and including up to twelve part length rods.

41. The invention of claim 35 and wherein said spacers include ferrule spacers.

42. The invention of claim 35 and wherein the upper spacer in said fuel bundle does not incorporate swirl vanes.

43. The invention of claim 35 and where the upper most spacer in said bundle is an inconel spacer having low pressure drop and minimal pressure drop on the passing two phase flow in said upper two phase region of said fuel bundle.

44. The invention of claim 35 and including:

at least one large water rod extending in said fuel bundle having moderator contained therein for providing to said upper two-phase region of said fuel bundle additional moderator for moderating reaction produced fast neutrons to reaction continuing thermal neutrons, said large water rod occupying a portion of the fuel rod positions in said fuel rod matrix.

45. In a boiling water reactor having discrete bundles of fuel rods confined within channel enclosed fuel assemblies, an fuel bundle comprising:

a fuel channel having vertically extending walls forming a continuous channel around a fuel assembly volume, said channel being open at the bottom end for engagement to a lower tie plate and open at the upper end for engagement to an upper tie plate;

a plurality of fuel rods for placement within said channel, each of said fuel rods containing fissile material for producing nuclear reaction when the presence of sufficient moderating water coolant;

a lower tie plate for supporting said bundle of rods within said channel, said lower tie plate joining the bottom of said channel close to said channel, said lower tie plate providing defined apertures for the inflow of water in said channel between said rods for the generation of steam during said nuclear reaction;

said plurality of fuel rods extending from said lower tie plate to an upward portion of said bundle wherein an annular flow regime of water and steam in said bundle is defined during nuclear steam generating reaction in said fuel bundle;

an upper tie plate for supporting the upper end of said bundle of rods, said upper tie plate joining the top of

said channel to close the top end of said channel, said upper tie plate providing defined the apertures for the outflow of water and steam in said channel from the generation of steam during said nuclear reactions;

at least one large water rod extending in said fuel bundle having moderator contained therein for providing to said upper annular flow regime of said fuel bundle additional moderator for moderating reaction produced fast neutrons to reaction continuing thermal neutrons, said large water rod occupying a portion of the fuel rod positions in said fuel rod matrix;

a plurality of said fuel rods being part length fuel rods extending from said lower tie plate towards said upper tie plate, said part length rods terminating within the annular flow regime of said bundle before reaching said upper tie plate to produce deceased pressure drop in said upper annular flow regime of said fuel bundle;

spacers intermediate said upper and lower tie plate at preselected elevations along said fuel rods for maintaining said fuel rods in spaced apart location along the length of said fuel assembly including a first group of spacers in said lower region of said fuel bundle and a second group of spacers in said upper annular flow regime of said fuel bundle;

improvement to said spacers comprising in combination:

said second group of spacers in said upper annular flow regime of said fuel bundle including swirl vanes to restore at least some of said decreased pressure drop whereby the critical power of said fuel bundle is enhanced.

46. The invention of claim 45 and wherein said spacers in said second group of spacers with said swirl vanes in the annular flow regime of said fuel bundle has the same pitch as said spacers without said swirl vanes.

47. The invention of claim 45 and wherein said spacers of said second group of spacers with said swirl vanes in the upper annular flow regime of said fuel bundle has an increased pitch over said spacers without said swirl vanes.

48. The invention of claim 45 and wherein said spacers include ferrule spacers.

49. The invention of claim 45 and where the upper most spacer in said bundle is an inconel spacer having low pressure drop and minimal pressure drop on the passing two phase flow in said upper two phase region of said fuel bundle.

50. The invention of claim 45 and including:

at least one large water rod extending in said fuel bundle having moderator contained therein for providing to said upper two-phase region of said fuel bundle additional moderator for moderating reaction produced fast neutrons to reaction continuing thermal neutrons, said large water rod occupying a portion of the fuel rod positions in said fuel rod matrix.

51. In the combination of a fuel bundle for a boiling water nuclear reactor, said fuel bundle including; a lower tie plate for supporting a matrix of vertically upstanding fuel rods and defining apertures for the inflow of water to said fuel bundle; an upper tie plate for maintaining said matrix of fuel bundles in vertical upstanding relation and defining apertures for permitting the outflow of water and generated steam; a channel surrounding said fuel bundle and extending from said lower tie plate to said upper tie plate for confining fluid flow between said tie plates and through said matrix of fuel rods; a plurality of spacers within said channel and around said fuel rods for maintaining the side-by-side spacing of said fuel rods between said tie plates; at least one of said fuel rods being a part length fuel rod resting on and supported by said lower tie plate and terminating at an upper end below said upper tie plate, said part length rod defining with respect to surrounding full length rods a void volume overlying said part length rod for defining a steam vent path between the upper end of said part length rod and said upper end of said fuel bundle, the improvement to said fuel bundle comprising:

a separation device supported by said fuel bundle and placed in said steam vent path overlying said part length rod and under said tie plate;

said separation device defining means for deflecting water from said steam vent path to said surrounding full length rods.

52. The invention of claim 51 and wherein said separation device is attached to the end of said part length rod.

53. The invention of claim 51 and wherein said separation device is attached to one of said spacers.

54. The invention of claim 51 and wherein said separation device is attached to said upper tie plate.

55. The invention of claim 51 and wherein said separation device includes a swirl vane.

56. The invention of claim 51 and wherein said separation device includes deflecting tabs.

57. The invention of claim 51 and wherein said separation device includes a cone, said cone disposed with the apex there of is downward disposed to and towards the end of said part length rod.

58. The invention of claim 51 and wherein a plurality of part length rods are placed within said fuel bundle and a separation device overlies more than one of said part length rods.

59. The invention of claim 58 and wherein a corresponding plurality of separation devices overlie said part length rods.

60. The invention of claim 51 and wherein said upper tie plate defines an aperture and said separation device passes through said upper tie plate at said aperture.

61. The invention of claim 51 and wherein said separation device includes a water rod with said separation device.

62. In the combination of a fuel bundle for a boiling water nuclear reactor, said fuel bundle including;

a lower tie plate for supporting a matrix of vertically upstanding fuel rods and defining apertures for the inflow of water to said fuel bundle;

an upper tie plate for maintaining said matrix of fuel bundles in vertical upstanding relation and defining apertures for permitting the outflow of water and generated steam;

a channel surrounding said fuel bundle and extending from said lower tie plate to said upper tie plate for confining fluid flow between said tie plates and through said matrix of fuel rods;

a plurality of spacers within said channel and around said fuel rods for maintaining the side-by-side spacing of said fuel rods between said tie plates;

at least one of said fuel rods being a part length fuel rod resting on and supported by said lower tie plate and terminating at an upper end below said upper tie plate, said part length rod defining with respect to surrounding full length rods a void volume overlying said part length rod for defining a steam vent path between the upper end of said part length rod and said upper tie plate;

a separation device supported by said fuel bundle and placed in said steam vent path overlying said part length rod, said separation device defining means for deflecting water from said steam vent path to said surrounding full length rods.

63. The invention of claim 62 and wherein said separation device is attached to the end of said part length rod.

64. The invention of claim 62 and wherein said separation device is attached to one of said spacers.

65. The invention of claim 62 and wherein said separation device includes a swirl vane.

66. The invention of claim 62 and wherein said separation device includes deflecting tabs.

67. The invention of claim 62 and wherein said separation device includes a cone, said cone disposed with the apex there of downward disposed to and towards the end of said part length rod.

68. The invention of claim 62 and wherein a plurality of part length rods are placed within said fuel bundle and a separation device overlies more than one of said part length rods.

69. The invention of claim 68 and wherein a corresponding plurality of separation devices overlie said part length rods.

70. The invention of claim 62 and wherein said upper tie plate defines an aperture and said separation device passes through said upper tie plate at said aperture.

71. The invention of claim 62 and wherein said separation device include a water rod.

END